Tactical Decision Making Under Conditions of Uncertainty: An Empirical Study

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Uncertainty is a fundamental characteristic of warfare. Military decision makers confront uncertainty when the data they encounter are incomplete (missing), ambiguous, or conflicting. This study examined how different categories of uncertainty (ambiguous/missing, conflicting, baseline) affect response time and type of decisions made in a low-fidelity tactical decision making task. Prior to the study, researchers elicited real-world tactical scenarios from veterans of Operation Enduring Freedom and Operation Iraqi Freedom in which uncertainty was present. Nine scenarios were developed from the interviews and were given to 28 participants at the Command and General Staff College, FT Leavenworth, KS. Participants were asked to make a decision; their responses were recorded and analyzed. The results indicate that the category of uncertainty and scenario difficulty were significant factors in response time and type of decision made. These findings have the potential to improve human behavior modeling, tactical simulations, and representations of complex task environments.

INTRODUCTION

A US Army Captain is commanding a remote forward operating base (FOB) in Iraq. He has three vehicles in his quick reaction force (QRF) that can respond to any unexpected event. During the last week, his attention has been focused on two areas, one a few kilometers to the north of his location, the other a few kilometers to the south. Both locations have been used to launch mortar attacks on his base. His standard response to these attacks has been to send the QRF out to locate and destroy the mortar sites. Standing in his tactical operations center (TOC) at 0100 hours, he is startled by an incoming mortar round that lands very close to the TOC. His most senior and trusted sergeant tells him the round came from the south. The company executive officer and a guard are convinced that the round came from the north. The QRF is not big enough to divide and respond in both directions. The commander must choose one direction and send out the QRF immediately to quell the attack. If he makes the wrong decision, the attack is likely to continue and his unit may suffer casualties.

This scenario is based on an actual event during Operation Iraqi Freedom. Military leaders at all levels routinely face uncertainty. In fact, uncertainty is a fundamental characteristic of warfare. Military theorist Carl von Clausewitz described the climate of war as having four distinct characteristics: danger, exertion, uncertainty, and chance. He wrote, "…war is the realm of uncertainty; three quarters of the factors on which action in war is based are wrapped in a fog of greater or lesser uncertainty…" (Clausewitz, 1984, p. 102). Uncertainty creates "friction" that makes the simplest movements difficult. This paper reports the results of an empirical study that examines the impact of various types of uncertainty on military decision making.

During the last four decades, researchers have proposed numerous definitions for uncertainty and developed a variety of taxonomies. They range from simple to complex and from those observed *in situ* to those empirically derived. Conrath (1967), for example, defines uncertainty as any moment where a decision needs to be made with an incomplete set of information. He constructed a scale using the terms "certainty" and "uncertain" as two extreme opposite points along a continuum. St. John, Proctor, and Holste (2000) parse uncertainty into three levels: high, medium, and low. They collected data on 120 Marines who participated in a Tactical Decision Game at all three levels of uncertainty. The researchers found that in the high uncertainty condition, Officers who had limited

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
SEP 2009		**00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Tactical Decision Making Under Conditions of Uncertainty: An Empirical Study	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Postgraduate School,Operations Research Department,Monterey,CA,93943**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Proceedings of the 53rd Annual Human Factors and Ergonomics Society, September 2009, San Antonio, TX.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Combat Operations Center experience chose the 'wait and see' option far more than their more experienced counterparts. However, there was no difference between groups with respect to the time it took for them to make a decision.

Cohen and Freeman (1996) constructed a simple taxonomy that suggested uncertainty results from data that are incomplete, conflicting, or unreliable. They conducted two studies in which US Naval Officers (60 in the first study, 35 in the second study) were trained on a method to help them cope with uncertainty during a simulated anti-submarine warfare scenario. The results of the study indicate that the trained Officers performed better than the untrained officers. The decisions of the trained Officers were more concise and timely.

Lipshitz and Strauss (1997) state that uncertainty is a result of the information presented and the alternatives available thereafter. The taxonomy they developed is based on the issue (i.e., what the decision maker is uncertain about) and the source (i.e., what causes the uncertainty). The three basic issues are outcomes, situation, and alternatives. The three sources are incomplete information, inadequate understanding, and undifferentiated alternatives. They analyzed stories from 102 Israeli Officers who had encountered uncertainty in their careers. They determined that the two greatest sources of uncertainty were inadequate understanding of the situation and conflict among alternatives. Lipshitz and Strauss distinguish uncertainty from ambiguity by describing the latter as "lacking precise knowledge about the likelihood of events" (p. 150). They also suggest that uncertainty in a particular context leads to a sense of doubt that will block or delay the appropriate response.

McCloskey (1996) identified four categories of uncertainty: missing information, unreliable information, complex information, and ambiguous/conflicting information. Moesner (2000) developed a decision support tool designed to organize information and reduce uncertainty. He identified six types of uncertainty, including uncertainty due to:

- contradicting or conflicting data;
- absence of critical data;
- questionable sources;
- risk;
- age of data (staleness);
- data that have been sanitized by higher security classification.

After reviewing and analyzing the taxonomies, it was clear that there were as many differences as there were similarities among all of them. Therefore, the researchers decided to develop a taxonomy that integrated as many of the characteristics of the taxonomies cited in this paper as possible. The result is the taxonomy in Figure 1.

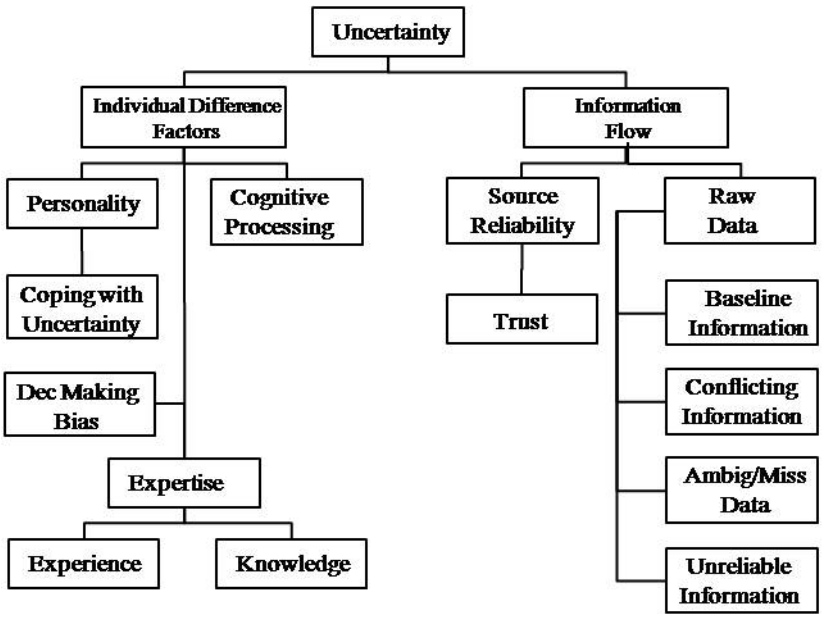

Figure 1. Integrated Taxonomy of Uncertainty

The researchers used this integrated taxonomy as the basis for their exploration of uncertainty. They conducted two pilot studies that presented selected types of uncertain situations to participants to determine if the categories of uncertainty led to differences in performance. The researchers also presented numerous subject matter experts with a variety of scenarios in which different types of uncertainty were embedded. The experts' task was to determine which type of uncertainty was present.

These studies revealed that, while it was difficult to classify some types of uncertainty, the experts were successful in classifying conflicting information scenarios, ambiguous/missing information (combined) scenarios, and baseline (no uncertainty) scenarios. In addition, the pilot studies indicated that participants seemed to reason differently about these three types of uncertain scenarios. These three uncertainty types (i.e., conflicting, ambiguous/missing, baseline) became the basis for the study reported herein. The researchers hypothesized that participants, when presented with baseline information, would reach a decision more quickly than if they were presented with either conflicting or ambiguous/missing information. In addition, the types of decisions they made (in terms of decisiveness) would be different.

METHOD

Participants

The participants consisted of 28 students attending the Command and General Staff College (CGSC), Fort Leavenworth, KS. There were 28 males with an average age of 37 years and an average commissioned service time of 13 years. Twenty-seven participants held the rank of Major, and one participant held the rank of Lieutenant Colonel. With respect to their branch type, 14 served in Combat Arms (CA), 9 served in Combat Support (CS), and 5 served in Combat Service Support (CSS).

Apparatus

Prior to the study, researchers elicited real-world tactical vignettes from veterans of Operation Enduring Freedom and Operation Iraqi Freedom in which uncertainty was present. Ten vignettes were developed from the interviews (one practice vignette and nine test vignettes). See Figure 2 for an example of a vignette. Three of the vignettes

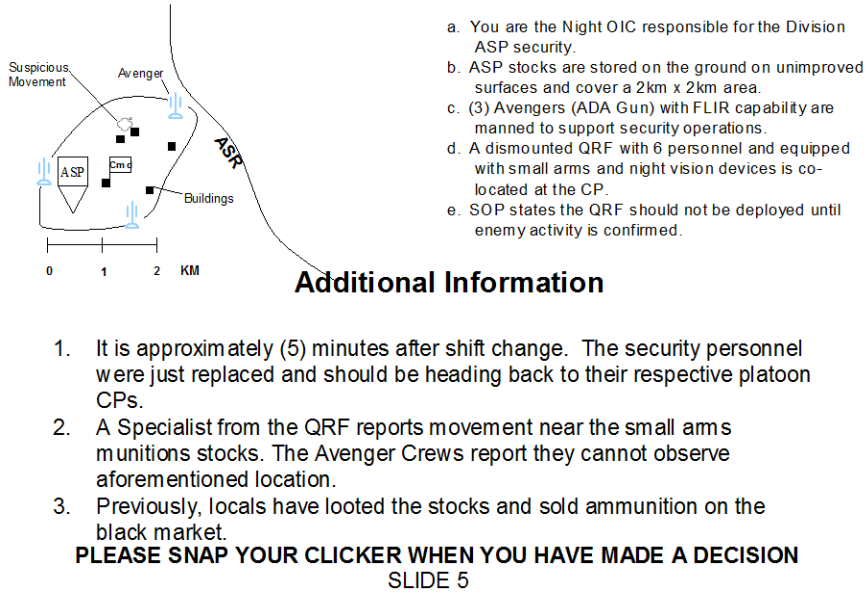

Figure 2. Example of a vignette with ambiguous/missing information. The sketch and the situation information appeared first. When the participant had finished reading and considering that information he signaled the experimenter with a clicker and the additional information was displayed.

contained ambiguous/missing information, three contained conflicting information, and three contained baseline (complete) information. The study was conducted in a CGSC classroom; the vignettes were presented using Microsoft PowerPoint and displayed on a 52 inch flat plasma screen television. Stopwatches were used as the primary means of recording the times. Digital voice recorders were used to record the comments of the participants and also served as back-up timers. Training "clickers" were used by the participants to signal to selected events during the data collection.

Procedure

The study was a within subjects design. All participants viewed every vignette. For each vignette, the time started when participants were shown the situation information. The participants read the situation information aloud. When they were ready to receive additional information, they snapped the training clicker. At the sound of the clicker, the experimenter logged the time, and the additional information was presented (with the situation information remaining visible). The participants read the additional information aloud. When the participants finished reading the last word of the additional information, the experimenter logged the time. When the participants were ready to make a decision, they snapped their training clicker and the experimenter again logged the time. The participants then answered two questions: (1) "What is your decision?" and (2) "How did you arrive at your decision?" Finally, the participants completed a demographics survey.

The participants were not placed under any time constraint by the experimenters. However, the situations with which they were presented were such that time was of the essence.

RESULTS

A Wilcoxon Sign-Rank Analysis for overall total time revealed significant differences among two of the categorical pairs of uncertainty. The total time taken for ambiguous/missing information vignettes was significantly greater than conflicting information vignettes ($p < 0.01$). The total time taken for ambiguous/missing information vignettes was significantly greater than baseline information vignettes ($p < 0.01$). Conversely, the researchers did not find a significant difference between conflicting information vignettes and baseline information vignettes ($p = 0.06$).

The researchers found a significant, positive correlation between all categories of uncertainty for overall total time: ambiguous/missing information and conflicting information ($r = 0.87$, $p < 0.01$); ambiguous/missing information and baseline information ($r = 0.84$, $p < 0.01$); and, conflicting and baseline information ($r = 0.8$, $p < 0.01$). Hence, if participants responded quickly to one category of uncertainty, they were likely to respond quickly to the other categories of uncertainty.

The decisions made by participants were reviewed by subject matter experts and placed into three categories: decisive, cautious, and passive. This analysis revealed that participants made significantly more decisive decisions (e.g., take immediate action to repel an attack or to quell a potentially hostile crowd) during baseline vignettes but more passive decisions (e.g., wait for the situation to develop or call higher headquarters and ask for guidance) during ambiguous/missing and conflicting vignettes.

DISCUSSION

The results support the hypothesis that there are significant differences between the categories of uncertainty with respect to overall total time. The results suggest that decision makers respond more slowly to situations with ambiguous/missing information compared to baseline information or conflicting information. The differences between ambiguous/missing information and baseline information were found in situation time, time to decision, and time to decision + additional time. As expected, ambiguous/missing situation time and ambiguous/missing time to decision were positively correlated. Thus, if participants spent a large amount of time considering the situation information, then they tended to spend a large amount of time to make a decision.

The finding that uncertainty influences the type of decisions made is extremely important. In spite of the sophisticated technologies present on the modern battlefield, uncertainty abounds. Military

leaders at all levels must cope with uncertainty but also must make decisions quickly if they are to be successful against a highly adaptive enemy.

Research in decision making under uncertainty has great potential. The study of human reasoning under uncertain conditions is critical to understanding the dynamic and unpredictable nature of war. The researchers are confident that the findings in this study will add to the body of knowledge of decision making under uncertainty and lead to improved comprehension of human performance on the battlefield. Additional research in this area is needed to provide greater understanding of the effects of uncertainty. The results of additional research coupled with improved modeling and simulation may prepare leaders to better cope with the inevitable uncertainty. These improvements have the potential to significantly impact the manner in which military leaders train for, reason about, and conduct military operations at all levels of war.

REFERENCES

Clauswitz, C. V. (1984). In Howard M., Paret P. (Eds.), *On war*. Princeton, NJ: Princeton.

Cohen, M. S., & Freeman, J. T. (1996). Thinking naturally about uncertainty. *Proceedings of the Human Factors and Ergonomics Society 40th Annual Meeting, 1*, 179-183.

Conrath, David W. (1967). "Organizational Decision Making Behavior Under Varying Conditions of Uncertainty." Management Science Volume 13, No. 8, pp. B487, April 1967.

Lipshitz, R., & Strauss, O. (1997). Coping with uncertainty: A naturalistic decision-making analysis. *Organizational Behavior and Human Decision Processes, 69*(2), 149-163.

McCloskey, M. (1996). An analysis of uncertainty in the Marine Corps. *Proceedings of the Human Factors and Ergonomics Society 1996, 1*, 194-198.

Moesner, John F. (2000). A Method of Focusing the Attention of the Decision-Maker on Uncertain Information. Master's Thesis. Air Force Institute of Technology Wright-Patterson Air Force Base School of Engineering.

St. John, M., Callan, J., Proctor, S., & Holste, S. T. (2000). *Tactical decision making under uncertainty: Experiments I and II* (Technical. Arlington, CA: Office of Naval Research.